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Interdisciplinarity in Integrated Environmental Research in Germany: Lessons From an Empirical Evaluation

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Abstract

Endeavours to understand the complex interactions between society and environment have stimulated a lively debate over the prerequisites for interdisciplinarity and integrated environmental research. One highly contested issue is whether, and to what extent, interdisciplinarity can be achieved within the framework of present academic structures, considering their strong disciplinary orientation. Some scholars see a need for a fundamental reorganisation of science and its links back to society, in order to be able to develop trans-disciplinary and problem-oriented knowledge. Other authors reject this position and highlight the need for strictly disciplinary research which then has to be integrated into interdisciplinary research by appropriate organisational means.

Against this background, this article describes to what extent the research organisation and research practices currently applied in major German university-based environmental research programmes can be said to be interdisciplinary and integrative. The programmes were also examined to find out how different outcomes could be explained.

The most important finding was that the full challenge of interdisciplinarity only becomes apparent during the actual research process. Being predominantly based on an additive form of integration of results, these research processes were multidisciplinary rather than interdisciplinary, but nevertheless produced an interdisciplinary "added value" beyond disciplinary perspectives. Variations in outcomes corresponded to differences in the organisation of the respective research processes and their management.

Thus, while this study confirms the dependency of interdisciplinarity on suitable organisational structures and endeavours, it also points to the need for developing a supportive academic culture.

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1 Introduction

Interdisciplinarity has become one of the leading issues in science today. While any endeavour to bridge different disciplinary traditions is demanding, the investigation of global environmental change constitutes a particular challenge to scientists seeking to come up with interdisciplinary results. Against the background of the impact of societal processes on the environment, any form of sustainable development requires a profound understanding of the interactions between societies and natural systems. However, given their completely distinct scientific traditions, methods and academic cultures, comprehensive and integrated collaboration between natural sciences and social sciences constitutes the most difficult type of interdisciplinarity.

Large parts of the literature on interdisciplinarity extensively investigate the obstacles that interdisciplinary research within the current academic system faces. Therefore, they demand a new type of problem and practice oriented knowledge production to foster sustainability (e.g., Jahn 2000; Weingart 1997). Other scholars have developed categories of possible actions that seek to overcome existing barriers within, and outside of, existing structures (e.g., Lange 2003). Others again propose new evaluative methods (e.g., Loibl 2001; Bergmann et. al. 2005). So far, however, re-assessments of ongoing changes in scientific practices, that aim to apply interdisciplinarity, are rare.

Since the mid-1990s, various research programmes in different countries have tried to address the most important aspects of global environmental change through interdisciplinary research, including both natural and social sciences. But to what extent were the results of the debate on interdisciplinarity taken into account? Did integrated research actually overcome the obstacles presented by the pre-existing disciplinary cultures and academic structures? Were the recommended organisational measures applied, and did they lead to measurable improvements regarding interdisciplinarity?

Within this context, our paper provides an overview over the state of interdisciplinarity in university-based projects in German integrative environmental research.

The findings presented in this paper are the result of a recent study conducted for the German Federal Ministry of Science and Education (BMBF) which aimed to evaluate experiences with interdisciplinary research and the application of integrative concepts and methods in major integrated research projects. The study investigated ongoing and recently finished German research projects on climate change, biodiversity and global change. Interviews with project co-ordinators focussed on project development, resources for interdisciplinarity, coordination, as well as integrative methods and concepts.

Our paper proceeds as follows: In the next section, the conceptual framework for our investigation will be outlined on the basis of a review of the recent debate on pre-conditions for interdisciplinarity, and an evaluation of this scientific approach. The third section describes the research approach and the methods applied. In the fourth section, the results are presented. The concluding section discusses how the different outcomes might be explained. While the study shows that interdisciplinarity and integration are indeed hard to accomplish within the present academic system, it also discusses the pre-conditions necessary to develop a supportive academic culture within the German science system.

2 The Challenges of Interdisciplinary Research: Conceptual Framework

The scientific analysis of relations between the environment and society requires research concepts which are able to combine a natural science perspective on environmental change with the examination of social and economic processes. At the same time, such research concepts should provide a normative orientation in accordance with sustainability. Such an orientation would thus set them apart from currently predominant discourses that are rooted within their own - often unconsidered – normative foundations.

In this context, various scholars of sustainability research have developed a broad understanding that disciplinary research concepts fail to recognise the complex interactions with which environmental research is confronted. According to these scholars, such concepts are thus incapable of offering adequate contributions to the development of an increased societal problem-solving capacity that is considered necessary to successfully address current environmental issues. Therefore, such concepts should be superseded by a new approach that should be freed of the intrinsic dynamics of traditional academic knowledge production. Such a new approach would aim to integrate theoretical concepts of environmental research from both, the natural and social sciences, combining them in a problem-orientated perspective. So-called “non-university based facilities for socio-ecological research”, especially, claim to be particularly successful in this respect, integrating problem and actor orientation in a trans-disciplinary framework (Jahn 2000).

In response to this call for a new type of science, various authors investigated the ambivalent relations between disciplinarity and interdisciplinarity, pointing to some core characteristics of the disciplinary science system that foster, or constrain, compatibility with interdisciplinary approaches.

Their reflections on the development of disciplinary knowledge are based on the following assumptions (e.g., Weingart 1997, Lange 2003):

- Disciplines undergo constant changes and should therefore not be considered static. In the light of a continuous differentiation of knowledge available in society, there is a growing potential and a growing need for knowledge to be reconfigured. This makes an evolutionary process within, and among, professional discourse communities (which is the underlying conceptualisation for disciplines and sub-disciplines applied here) inevitable — and, furthermore, provides the opportunity for new areas of knowledge to develop.
- In actual fact, interdisciplinarity is not a recent phenomenon. There have been many circumstances historically (military or medical challenges, for instance), when societal needs, formulated through state programmes, forced science to overcome traditional disciplinary boundaries, thereby challenging the relations between scientific theory and practice.
- The perception that there has recently been a shift in the science system from disciplinary towards application-oriented research, overlooks the empirical evidence that research has always been predominantly applied or problem-oriented.
- However, there do exist new, non-disciplinary forms of knowledge production that fulfil an important role in dealing with societal problems. These tend to only chiefly emerge in cases, or historical contexts, in which technologies are new or controversial, and there-

fore become a political issue. In a sense, problem-oriented forms of knowledge production have the function of broadening the basis of available knowledge, of making such knowledge accessible to the public and/or specific groups. Thereby, science may provide crucial prerequisites for societal bargaining processes between conflicting interests within a democratic society.

Against this background, interdisciplinarity should not be perceived in fundamental opposition to disciplinary specialisation, but should be developed out of the relevant specialist areas and respective disciplines to meet the specific requirements of the issue at hand. The aim is thus to overcome, wherever necessary, any restrictions imposed by the specialisations and internal differentiations that are essential in any discipline. The necessary competencies for interdisciplinary co-operation must be developed through reflection within the individual disciplines about the suitability of their approach for the particular issue in question (Defila et. al. 2000).

For a variety of reasons, this conceptualisation constitutes a particular challenge for the integration of natural and social sciences, which is deemed to be imperative for effective interdisciplinary co-operation in environmental research. It is undisputed that environmental research is dominated by the natural sciences; this is not least due to the advantage of thematic leadership they gained over the social sciences through the earlier development of ecosystem research. Moreover, while this branch of research provides a paradigm that is compatible with various sub-disciplines of the natural sciences, it is at the same time inapplicable to societal processes.

The problem is compounded, first, by the difficulty of linking the predominantly quantitative methodological orientation of natural sciences to qualitative approaches preferred by social sciences, but also by the question of how to deal with switches between descriptive-analytical and normative perspectives. At the same time, social sciences often also face exaggerated expectations in terms of identifying political and societal regulatory mechanisms (Daschkeit 1998, Fuest 2004).

This raises the question of how interdisciplinary co-operation — particularly between natural and social sciences in German environmental research — actually works, and how it functions within an academic system that is structured according to disciplinary categories. What results does German interdisciplinary environmental research produce under these conditions, and how does it overcome the empirical obstacles mentioned above?

While these issues are investigated and discussed in relation to German research programmes, the findings clearly hold international implications as well, since most of the research was carried out within the context of global change research programmes that explicitly emphasise the relevance of integrated and interdisciplinary research in their science plans and implementation strategies (e.g. IDGEC 2005).

There are already a number of contributions based on experiences gained from integrated interdisciplinary projects currently in progress that reflect on, and discuss, the concept, reality and conditions for success in such projects. One crucial requirement for ensuring interdisciplinarity identified in these studies is the close co-operation of the participating scientists, not only during the initial conceptualisation of projects but also in terms of co-ordination and communication during the actual research processes (Schuchardt 2002).

However, these contributions also point to some limitations of, and constraints imposed on, such projects:

- The communication necessary for interdisciplinary project development is often hampered by chronic problems with time budgets for co-ordination.
- Experience shows that in some cases scientists approach other disciplines on the basis of stereotypes and outdated information, thus hindering the innovative integration of disciplines based on the state-of-the-art knowledge. This seems to happen particularly often in communication between natural and social scientists (Fuest 2004: 7).
- As a result of the currently prevailing academic and research structures, the participating researchers have to fulfil certain obligations in terms of promoting their profiles within their respective disciplines. These expectations affect interdisciplinary co-operation inasmuch, as the products of their joint research work have to fit into the respective disciplinary contexts in order to support their individual career development. The academic career system thus tends to impede career progress for those working in an interdisciplinary context (Parthey 1996: 103).
- There are yet other obstacles to the development and implementation of joint research organisation as a result of the existing academic and research structures: While research at universities is primarily characterised by a decentralised organisation of, and relative autonomy for, the individual research groups, interdisciplinary co-operation requires a high degree of co-ordination and commitment in terms of drawing up and keeping to joint time schedules. Project managers thus face the task of finding equilibrium between effective leadership on the one hand, and a professional understanding of science on the other hand which, to a large extent, rules out hierarchical structures (Daschkeit, Schuchardt 1999). Often, such crucial management and co-ordination tasks are then put into the hands of junior researchers, which raises doubts whether the necessary degree of professionalism is always ensured (Fuest 2004).
- Another task within large-scale project networks or groups is that of ensuring intense communication among the sometimes numerous subprojects. This can entail the formation of hierarchies between core and secondary projects. The integration of inexperienced junior scientists into the complexities of interdisciplinary co-operation is particularly demanding for integrated projects (Berger et. al. 1999).

In light of such numerous critical references to fundamental problems that need to be overcome in connection with interdisciplinary research, some authors conclude that despite widespread proclamations, interdisciplinarity actually only takes place by chance (Fuest 2004).

At the same time, however, these critical analyses allow us to identify factors that should be developed and promoted specifically as a basis for successful interdisciplinary co-operation. Following Fuest, these factors for success aim, *first*, to reduce epistemological distances, *secondly*, to provide the organisational prerequisites, and *thirdly*, to support institutional development:

- Reducing epistemological differences basically requires the *joint* construction of the research object, i.e., the formulation of a clear objective that allows for the operationalisation of sub-questions. Equally important are: a clear delineation of the thematic area,

as well as of the organisational structure; the description of separate tasks, and of the intended research products (ibid. 16; Daschkeit 1998).

- Setting up a stable communication network within, and among, the project groups is a vital pre-condition for the smooth organisation of integrated interdisciplinary research as well. This is ensured through joint research activities, detailed operational plans, the provision of glossaries, locational proximity, and regular thematic meetings and workshops (Scheuermann, Spada 1999). Additionally, it is important to foster a corporate identity and an organisational culture of trust (Fuest 2004).
- It is within the purview of the funding institutions to develop and ensure favourable institutional frame conditions for interdisciplinary co-operation by modifying their research funding practices. This could include aspects like adjusting the funding guidelines, selecting and training reviewers appropriately, as well as fostering the interdisciplinary orientation of academic education on a long-term basis. A further option would be to support extramural working groups and institutions that specialise in interdisciplinarity (Jahn 2000).

These requirements for successful interdisciplinarity can only be fulfilled by involving all actors and components of the existing academic system in a purposeful process of reorganisation and development. Within this process, both, the participating scientists and universities, and the funding institutions and research policy-makers face considerable responsibility for developing the necessary scope conditions and incentives.

But where does interdisciplinary environmental research stand today in German research practice? How do the German research workers overcome the organisational and epistemological challenges outlined above, and how do they assess the frame conditions laid down by research funding institutions? How do practitioners of interdisciplinary co-operation evaluate their experiences with these restrictions, their scope for action and, finally, the importance of change?

3 Research Approach

The findings presented in this article, as a contribution to the ongoing reflections on interdisciplinary research, were originally prepared within the context of the German climate research programmes, funded by BMBF. Of the 93 research groups and associations active in the fields of climate research, biodiversity and global change research, 21 recently completed or ongoing collaborative projects were selected for the study. Collaborative research programmes in the field of social ecology began later, and were therefore not included.

The prevalence of projects participating in global change research programmes is not coincidental, for two reasons. First, global change is a prime example of problem-oriented research that necessitates interdisciplinarity. Secondly, apart from the fact that a considerable proportion of the funding actually came from German sources¹, participation in these programmes also provided German scientists with a great opportunities for interdisciplinary research. German social sciences are, according to some critics, typically not well integrated into

¹ According to the IHDP website, the BMBF alone provided 50% of the IHDP budget in 2003.

global change research. This is attributed, at least partially, to disciplinary deficits, such as insufficient internationalisation (Biermann, Dingwerth 2001). However, while the scope of our study did not allow for a comparative assessment of the influence of national science systems, the disciplinary self-reflections of social sciences within these international programmes indicate that these problems (i.e., the limited number of relevant contributions of social sciences) are not restricted to the German participants alone (Biermann 2005). The results may thus contribute to debates on the organisation of German research, and – to a lesser degree – provide material for further discussions on interdisciplinarity in general.

Notwithstanding these restrictions, our study was part of a line of evaluation procedures which were developed for interdisciplinary research programmes, and designed either as project-related discursive investigations of interdisciplinary project work (Bergmann et. al. 2005), or as comprehensive international surveys (Loibl 2001).

Our aim was not to provide an extensive evaluation of interdisciplinary environmental research, but to investigate the experiences made by collaborative research associations and groups in an interdisciplinary context.

In this way, we hope that our study will make an empirical contribution to the discussion in terms of structures, instruments and types of organisations. The investigation focused on the following five thematic areas which proved to be of particular value in evaluations of interdisciplinary environmental research (Bergmann et. al. 2005):

- Project development:

Information was gathered on how, and by whom, the projects were developed (top-down or bottom-up), and to what extent the contributions of sub-projects were already defined during the preparatory phases. This was done in order to gain insights into the character of project development.

- Disciplinary orientation and composition of the collaborative research associations:

Data was collected about the participating disciplines, their contributions, the main areas of research, and the discipline that initiated collaboration (disciplinary configuration). Further, the relevance of other factors was investigated, such as locational proximity between the research partners, and already existing personal relations. Another point of interest were co-operation structures.

- Prerequisites for interdisciplinarity:

The study investigated to what extent participants had had previous experiences with interdisciplinarity, whether further training about problems of interdisciplinarity was organised, whether a common terminology was developed, how interdisciplinary collaboration developed in the course of the project, and how project members' identification with the research group as a whole could be characterised.

- Management and co-ordination:

A further point of interest was whether the collaborative research groups had specialised organisational units to carry out managerial and co-ordinating functions, and what resources (staff, project extension) were available for these tasks. The evaluation also examined the managerial and regulatory capacities the project co-ordinators or speakers were given.

- Concepts and methods for integration

Here, the investigation focussed on experiences gained with integrative concepts (e.g., syndrome or risk concept) and integrative methods or instruments (e.g., GIS-data bases, decision-support systems). It was examined whether such concepts or methods were applied, and if so, which ones; what results were achieved using them; and what "products" the collaboration finally presented.

Methodologically, the evaluation was based on expert interviews with researchers who had a central position in initiating and co-ordinating large-scale collaborative research projects, such as BMBF-funded integrated projects, or DFG-funded special research units². In some instances, the interviewees were academic researchers employed as administrative co-ordinators.

4 Experiences With Interdisciplinary Research Processes

4.1 Project development

The co-ordination of project development varied considerably among the research networks and groups under investigation. In a few instances, the initiators drew up a research design and later co-opted suitable partners, but in the majority of cases the research question was formulated, and then further developed in a second stage, in dialogue with other research partners. In the assessment of researchers from this second type of project, there was no viable alternative to this procedure. While in such cases the central idea, and sometimes also the basic structure of the project were developed by a single initiator, or a small group, they were often considerably altered in the course of the subsequent dialogue with new partners, in order to develop suitable interfaces for the sub-projects. The initial core-group members had often already established good working relations, or were located at the same university, or within the same region. Top-down approaches, in contrast, gave rise to various problems during the subsequent collaborative phase, as the sub-projects could not be integrated smoothly into the predefined concept. In a small number of cases, both the research question and the research process were jointly designed by all participants. These projects were either exceptionally small, showed a low degree of integration, or were of an experimental nature.

For the integration of all elements of the project groups, for more effective organisation, and for the successful completion of the entire project, it was considered extremely important to draw up joint workflow schedules with agreed times for delivery of intermediate results, to ensure transparency to all participants. The laying down of binding work procedures and delivery dates at an early stage in the initial development phase of labour was seen as highly conducive to disciplined co-operation, intense communication between participants, and to ensuring that individual contributions were transparent to all partners. Milestones set for the whole collaborative research group or network give structure to the whole collaborative pro-

² The 'Deutsche Forschungsgesellschaft' (German Research Society) is the central institution in the German science system for organising peer reviewed research and the provision of funding. The DFG is financed by the Federal Government and controlled by scientist representatives. While the BMBF funding policy supports problem-oriented research, DFG is concerned with basic research.

cess, and schedule the most important occasions for communication between project groups in the course of the research work. Due to the mutual dependency of highly integrated projects, it was particularly necessary for such projects to closely synchronize the deadlines and scope of individual work stages. In order to assign resources for field work that was often carried out conjointly in complex international projects, reliable interfaces between the frequently numerous sub-projects had to be determined in advance, too.

Projects in which the development of binding work schedules was not sufficiently defined were occasionally confronted with considerable problems, when trying to maintain a mutual understanding of the general project aims, and ensuring a coherent research process.

At the same time, many interviewees highlighted the necessity of adjusting the research process to suit changing scope conditions, which demanded flexibility of both, individual sub-projects, and project groups. While assessments of the needed extent of such adjustments varied, there was consensus that the funding institutions generally reacted with the necessary flexibility.

4.2 Disciplinary orientation and the composition of integrated projects

A majority of interviewees saw a close relation between the projects' fundamental disciplinary orientation, the main mechanisms for integration, and the type of labour division among sub-projects. These elements can thus be regarded as the disciplinary configuration characterising large scale co-operation. All interviewees agreed that the basic mutual understanding necessary for an integrative research approach has to be developed through discussion.

In terms of disciplinary orientation, the investigated projects were primarily from the natural science disciplines. While one group with a wide spectrum of natural sciences disciplines was supplemented with some social science aspects, an equally important second group of projects had a balanced orientation towards, both, social and natural science aspects. Only a small minority of projects was predominantly social science-oriented. In terms of disciplinary range, between 5 and 10 disciplines were involved in large-scale projects, and 3-6 disciplines in smaller and medium-sized projects. Particularly the natural science disciplines showed a remarkable heterogeneity which also led to a corresponding variety in research methods, and traditions of thought. It was considered crucial in all types of disciplinary constellations to establish methodological compatibility between different schools of thought. However, embedding social science sub-disciplines into integrated methodologies was frequently claimed by natural scientist to be problematic.

In addition to the anticipated results, the interviewees also found that interdisciplinary research has a remarkably synergistic effect, giving rise to new research initiatives, and the promotion and stabilisation of interdisciplinary scientific networks. This applies especially to projects that induce intense interdisciplinary communication by means of a highly integrated methodology and operationalisation. At the same time, this type of project is particularly demanding and requires intense communication. However, even in the majority of collaborative projects in which the tasks of the sub-projects were more distinctly separated, a number of interfaces were provided for the distribution of research results. Naturally, a more advanced form of integrated research management was required for such projects.

On the whole, interviewees from collaborative project networks in which all, or at least the majority, of participants were situated in the same, or in neighbouring, localities rated their internal communication considerably higher than those in scattered localities. Projects with a clear locational centre also less frequently experienced competition and conflicts as severe problems. Initially unintended research outputs were mentioned more often, as by-products of close co-operation. Project groups at separate geographical locations emphasized the considerable efforts arising from such locational distance. The situation was especially difficult for project groups with partners in other countries: They provided the largest, and thematically most complex, collaborative networks, and therefore applied less strict standards to their internal communication.

Despite their crucial importance, some interviewees observed that less time and resources were devoted to workshops and meetings than would have been appropriate. The decisive factors in this context were the locational proximity of sub-projects to each other, and the size of the entire project. In projects concentrated in one location, workshops were held up to six times a year. International projects with overseas partners reported only a frequency of one or two meetings a year, which, due to their size, had the character of conferences, and hence were less intense in terms of communication. In their assessments, the interviewees distinguished between the management level, and the shop floor level, where research assistants often co-operated closely on a bilateral basis, in addition to their regular project work within the sub-projects. In large-scale projects with distinctive and formalised committees (e.g., extended executive boards), meetings that included all participants took place less frequently, even when the project partners were situated in one locality.

The following frame conditions were thus considered crucial for any well-functioning internal communication within interdisciplinary projects:

- A close locational proximity between all participating sub-projects is both, less time-consuming, and less costly at all levels (for meetings between executive management and the teams, for all participants, and for bilateral co-operation between researchers), and facilitates more frequent meetings and more intense collaboration.
- Previously established work relations between partners are important as well, as they reduce the necessity for co-ordination, and the significance of locational proximity. In the majority of cases, the initiators and later co-ordinators of projects had already had experience in interdisciplinary research (though not necessarily together), which might indicate a diffusion of research experience over time. However, in principle, all the scientists interviewed were able to develop good working relations with new partners, provided that there was an interest in joint project outcomes. Good personal relations between research partners are thus of particular importance in this context.
- The decisive venues for internal communication between the projects are workshops and executive meetings. Meetings at the managerial level and between researchers take place more frequently than meetings comprising all participants. The type of meeting (workshop, conference, etc.) depends on the size of the collaborative project. While the costs of holding meetings are particularly high for international project networks, the communication in these projects is often reinforced by joint research stages and field visits.

The interview partners thought that making appropriate allowances for these aspects of communication, both in terms of resources (as part of the funding application), and in the

conceptual design (in the schedules of research applicants), was a crucial factor for success of integrated interdisciplinary research projects.

4.3 Prerequisites for interdisciplinarity

Only a small proportion of the research partners within the projects had had previous experience with interdisciplinary collaboration, and in most cases, the researchers in question were the initiators, or members of the core teams. Further, these were predominantly cases in which the same team had already collaborated in other projects.

With regard to the development of interdisciplinary co-operation in the course of the project, the interviewees reported two distinct, but equally valid, patterns of either continuous, constant co-operation, or episodic co-operation occurring at important stages, such as during the preparation of intermediate or final reports.

The participating researchers' identification with the project as a whole was reported to vary considerably. In most cases, a high to very high degree of identification was reported. The criteria for this assessment were indicators, such as participation at workshops and meetings, the quality of contributions, or the degree of willingness to take on additional tasks for the project.

Tab. 1: Identification of Participating Researchers With the Interdisciplinary Project (Cases)	
High or very high	12
Differences between research assistants / management	2
Strong differences between sub-projects or very low throughout the project	4
No response	3

Competition among participating researchers often occurred when it came to the distribution of resources, the form and direction of public presentations, and the publication of research results containing data from various sub-projects. The problem of authorship and copyright over research results was the main reason why some collaborative projects avoided interdependencies between sub-projects. However, most interviewees thought that such aspects did not lead to any problems in co-operation, despite the absence of formal agreements.

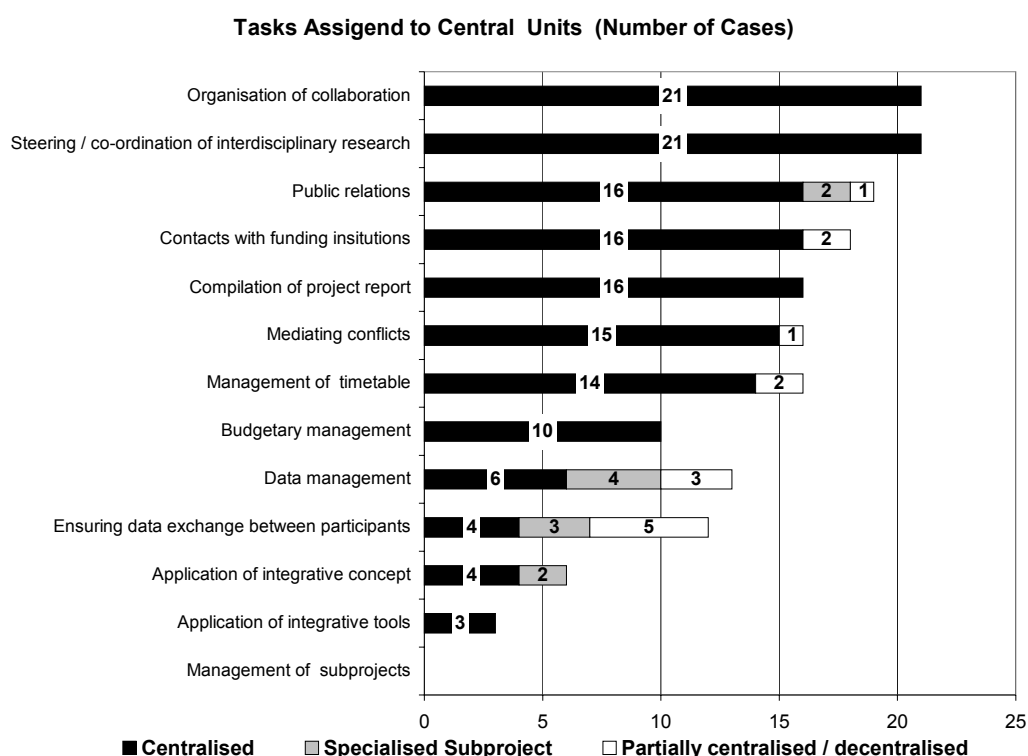
Although there are formalised instruments for fostering collaboration (such as joint glossaries, training and reflection workshops, copyright agreements, behavioural codices), most projects chose informal or graded solutions. Interestingly, project networks preferring a low degree of formalisation did not face any more problems than those that introduced formalised structures. This indicates that whether or not such instruments are used, is a question of the preferred communicative and collaborative style within the projects.

4.4 Management and co-ordination

Despite the fact that most of the projects surveyed were furnished with management support staff, the majority of co-ordinators felt they had insufficient resources for this task. The chief cause for this deficit was attributed to the donor institutions' funding policy which in the co-ordinators' point of view systematically underestimated, both, the importance and scale of these tasks.

In the majority of collaborative projects internal co-ordination and communication were organised as central assignments, or – in the case of joint research activities – were managed jointly. A second type of tasks, such as the thematic co-ordination of the sub-projects, was assigned in full to the research partners; other tasks, such as budgetary management, were essentially the remit of the individual sub-projects which, in some cases, even received additional separate funding. As a rule, data administration and communication between the participating sub-projects was only supported centrally, since complete provision through specialised staff would have been far too complex.

Tab. 2: Assessment of Recourses for Co-ordination (Cases)	
Resources appropriate	9
Resources inappropriate	11
No response	1



Collaboration in all the projects examined was primarily based on communication, whereby the crucial factors for successful management, apart from the steering committees, were seen to be the commitment and personality of the co-ordinators. This also applied to the management of conflicts or contradicting interests. Clearly, for the capacity to steer research processes, the participants' willingness to co-operate was decisive. However, the majority of the interviewees thought that this was indeed the case, even to a strong extent. From their per-

spective, improvements would essentially depend on further resources being made available for upgrading communication. Stronger hierarchies, as means to structure communication, were rejected by nearly all interviewees.

In a minority of cases, the steering capacity of interdisciplinary projects was assessed as only moderate, due to their dependence on the participating scientists' ability to reach agreements. Here, the importance of binding work schedules and pre-defined results was emphasized for ensuring everybody's commitment. Seen thus, the steering capacity could be improved through the application of monitoring instruments, and the extension of internal contract relations.

4.5 Integrating concepts and methods

The methodological integration of the individual disciplinary approaches used in sub-projects into the project network as a whole does not, according to the majority of interviewees, necessarily require an overarching theoretical integration into a shared scientific concept. Consequently, integrative theoretical concepts, such as the syndrome approach, were rarely applied.

In contrast, when working on complex research problems, all interviewees considered the application of integrative methods and research tools to be indispensable for addressing the various aspects of the research issues appropriately. For this reason, all projects, except one, applied at least one integrative research method in their collaborative research work. In particular, models, geographical information systems (GIS), decision support systems (DSS), and scenarios were used that permit a pragmatic inclusion of research results, elaborated on the basis of different theoretical concepts.

Tab. 3: Type of Integrative Methods (multiple responses possible) (Cases)	
Modeling	8
Geographic Information System (GIS)	7
Decision-Support-System	5
Scenarios	4
Databases	2
Others	5

One of the most important effects of integrative methods, highlighted by the interviewees, was that the methods structured the collaboration and the conflation of the results, and forced the participating sub-projects to operationalise their respective issues in a mutually compatible way, thereby avoiding narrow disciplinary perspectives and operationalisations. The added value, besides a more intense identification with project activities, was the synergistic effect of interdisciplinary project work. Further benefits mentioned were the development of common terminologies and conceptual understanding, as well as the avoidance of redundancies.

The high degree of mutual dependence between research partners was seen as a particular problem, since it may in some cases complicate the external presentation of disciplinary research results, and possibly lead to conflicts about the disciplinary orientation of the entire project. In terms of professional standards, the integration of various disciplines raised some concern about qualitative shortfalls in the research results of individual disciplines. Overall, however, despite certain organisational difficulties, the exchange of data and research results

within the scientific production chain nonetheless resulted in increased integration. Problems mainly arose as a result of delays in the delivery of intermediate results, which in turn led to delays in the schedules of the work groups waiting for those results. However, these difficulties were regarded as normal management problems.

Only a minority of the collaborating projects applied integrative methods extensively across disciplines, while most projects were restricted to natural science sub-projects only, or incorporated the results of other disciplines into their work after completion.

In about half of the projects under survey, the effort made to apply integrative methods was considerably higher than scheduled. This was essentially due to the low degree of relevant methodological experience and necessary additional specialisation in the participating research groups, while the task of methodological integration itself proved to be more demanding than predicted. Based on their experiences, the interviewees expected that more careful planning during the preparatory phase might lead to improvements. This would, at least partially, require more investment in time and financial resources. In the cases investigated here, such requirements were met through additional communicative efforts.

Suggestions for further improvements point, first of all, to the need for additional resources for planning and the application of integrative methods; secondly to additional support through further training; and thirdly to the continuous development and generalisation of standards for interdisciplinary work techniques.

5 Conclusion

The survey of interdisciplinary integrated projects in German environmental and sustainability research, based on interviews with project co-ordinators and spokespersons, sheds light on the present developmental stage of integrated and interdisciplinary research practices. It illustrates how central organisational challenges are addressed during the research process, and how they are reflected by the participating scientists.

The most important finding is that the full implications of interdisciplinarity are often only recognised and acknowledged during the actual research process, and must then be addressed through additional communication. Since scientific outputs are predominantly the result of a work structure based on disciplinary specialisation, the research processes tend to be multidisciplinary rather than interdisciplinary. However, as a result of considerable efforts to cope with the requirements of interdisciplinarity these projects nevertheless produce an interdisciplinary "added value" which exceeds the perspective of single disciplines.

The findings of our investigation thus confirm the positions that highlight the fundamental importance of integrative project management and research organisation across all disciplines, and throughout the entire scientific production cycle. The central task that needs to be addressed is the development of scientific work forms that guarantee the continued integration of disciplinary research questions, methods and research results into the joint work process.

The integration of social and natural science approaches and methods remain a crucial challenge for research practice. Some interviewees from projects with a strong natural-science orientation attributed these challenges to the difficulties of the social sciences in adhering to

the scientific standards, perspectives and methods of the natural sciences. Such reflections demonstrate how important it is that project networks and groups develop a mutual understanding of the different scientific cultures.

The fact that the majority of the projects interviewed managed to develop such an understanding in the course of the research process, has undoubtedly contributed to a considerable enlargement of the stock of experiences with interdisciplinary co-operation within the German research community, thus building essential capital for future research.

As it can be assumed that the capability to deal with the requirements of integrative research in terms of quality and management has increased, this experience should be used for future interdisciplinary research programmes. Furthermore, a substantially large pool of experts who dispose of the appropriate experience is finally available for peer reviewing.

It should be emphasized, however, that organisational difficulties encountered in interdisciplinary collaboration cannot solely be attributed to epistemological differences between the disciplinary traditions, but must also be seen as a consequence of the university system, which is based on the autonomy and accomplishments of the individual professor. Such an academic culture is incompatible with the complex and binding work structures required for interdisciplinary and integrative projects, which are often perceived as an imposition that the researchers are then left to deal with on their own. This explains, at least partially, the crucial importance of interpersonal qualities and abilities, needed to cope with the demands that come with the development of organisational cultures of large-scale and long term collaborative research.

On the basis of our survey, it is, however, impossible to predict whether the additional interdisciplinary studies and networks that arose among research assistants, and which were, by all means, positively acknowledged on the part of the project co-ordinators, will lead to more interdisciplinary science, or whether they will – as is often feared – hamper these junior scientists in developing the type of professional profile that is necessary to advance within the traditional hierarchical and disciplinary academic system. For a large number of young scientists, this remains to be seen.

It is possible, on the basis of our evaluation, to derive recommendations for further developing the organisation of interdisciplinary research, and for research funding practices in Germany. The goal of these recommendations is to encourage the advancement of interdisciplinary and integrative research practices through improved research management. Our most important recommendations concern:

- (1) The project development phase and initial work schedule: Here, we recommend to foster the development of detailed, binding research plans, and above all, to reduce unintentional interfaces; to avoid competition within the project association/network; and to prioritise internal communication.
- (2) Project management: A stronger emphasis should be placed on steering and co-ordination.
- (3) The use of integrative concepts and methods: Here it is essential that detailed task planning is accomplished in good time – in terms of allowing sufficient temporal flexibility, qualification and experience, and interface management.

These recommendations and findings are in line with important positions in the debate on interdisciplinarity that emphasize the relevance of both, research organisation, and funding policies (e.g. Lange 2003). While this may come as no surprise, they nevertheless challenge fundamental aspects and features of the German academic system.

The strong emphasis on the autonomy of professors, for example, as the predominant organisational principle of German science fosters a work orientation characterised by individuality. In social sciences, especially, this has led to a high degree of work being carried out in small-scale projects, compared to both the natural sciences, and international standards. The institutional framework provided by federal and state governmental science policy and research funding has stabilised these prevalent structures. For a long time, it has hindered the development of coherent and reliable incentives towards more complex co-operative structures.

Since an involvement in the global change programmes demands an interdisciplinary orientation, as well as the willingness to develop a scientific work orientation based on integration within fluent but, at the same time, rigid organisational structures that require co-operation and commitment, the funding of international global change research can be seen as an important incentive for "organisational learning", particularly within the social sciences. Despite the fact that social science disciplines still have to define their role and expand their contribution to these global change programmes (Fues et. al. 2005; Biermann 2005), the scientific orientation of these projects may serve as an important point of reference for such necessary learning processes.

Paradoxically, the current restructuring which takes place within the German academic system may function as a driving force towards interdisciplinary and integrated research. This process is a corollary of severe budgetary problems, and an increasing orientation towards international competitiveness in terms of both, scientific excellence, and expected stimuli for innovation in society (e.g., in the case of the so-called excellence initiatives). As a result, all disciplines now face strong institutional pressure to concentrate on fewer issues, and operate in larger contexts. While this development raises deep concerns about the effects of insufficient resources for science and research, such pressures on existing structures may also lead to institutional changes which are prerequisites for the introduction of innovative research concepts. Since these frame conditions are expected to prevail, and since some of the required adaptations (such as integration into broader co-operations) are analogous to requirements of interdisciplinary research, an interdisciplinary orientation may prepare the ground for co-operation with partners, and thus offer attractive niches for sustainability research. Thus, what so far appeared to be a voluntary individual effort to overcome structural constraints may become a rational exploitation of a window of opportunity in the future.

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